SYSTEMS THINKING: Visual Tools for Increasing Student Learning

Systems Thinking and Dynamic Modeling Conference
June 29, 2002

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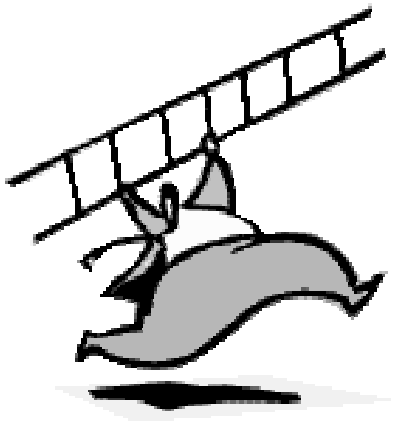
Connections with Best Practice



- Classroom Instruction That Works
- Dimensions of Learning

INSTRUCTIONAL STRATEGIES THAT AFFECT STUDENT ACHIEVEMENT

- **Identifying similarities and differences**
- **Summarizing and note taking**
- **Reinforcing effort and providing recognition**
- **Homework and practice**
- **Nonlinguistic representations**
- **Cooperative Learning**
- **Setting objectives and providing feedback**
- **Generating and testing hypotheses**
- **Questions, cues, and advance organizers**

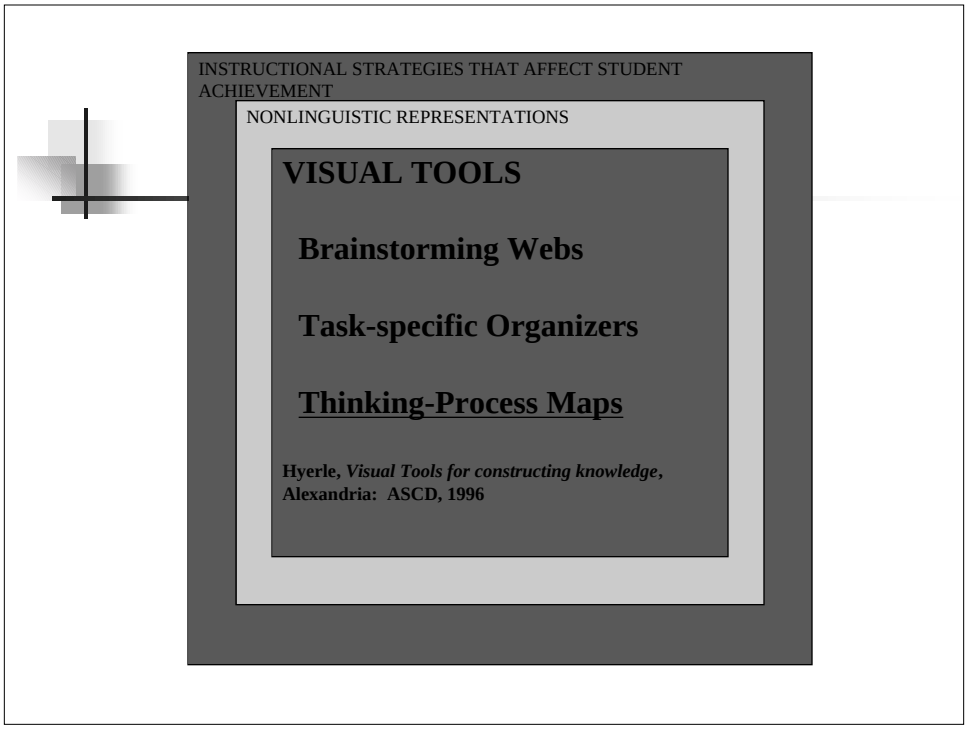
Source: Marzano, Pickering, and Pollock , *Classroom Instruction That Works: Research-Based Strategies for Increasing Student Achievement* (Alexandria: ASCD, 2001)

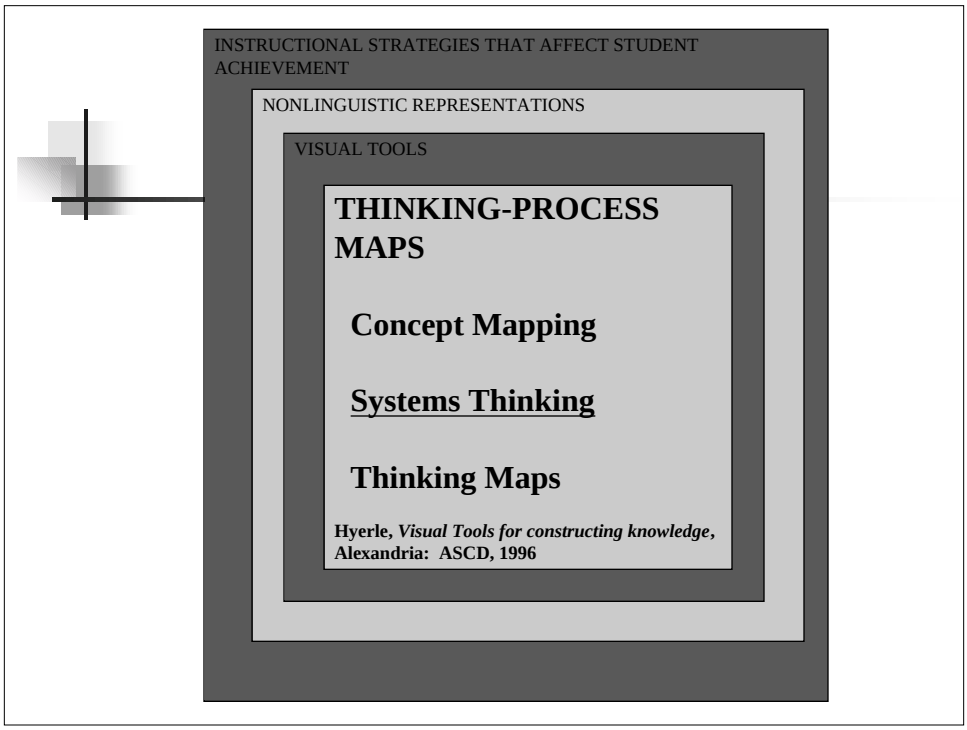
INSTRUCTIONAL STRATEGIES THAT AFFECT STUDENT ACHIEVEMENT

NONLINGUISTIC REPRESENTATIONS

- **Visual Tools**
- **Physical Models**
- **Mental Pictures**
- **Pictures and Pictographs**
- **Kinesthetic Activity**

Source: Marzano, Pickering, and Pollock , *Classroom Instruction That Works: Research-Based Strategies for Increasing Student Achievement* (Alexandria: ASCD, 2001)


INSTRUCTIONAL STRATEGIES THAT AFFECT STUDENT ACHIEVEMENT
NONLINGUISTIC REPRESENTATIONS
VISUAL TOOLS
Brainstorming Webs
Task-specific Organizers
Thinking-Process Maps
Hyerle, Visual Tools for constructing knowledge, Alexandria: ASCD, 1996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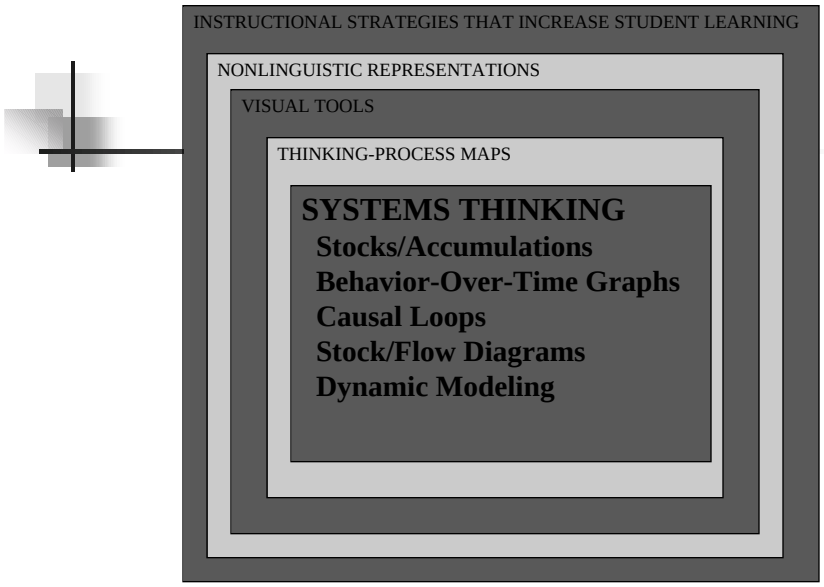


Dimensions of Learning

Dimension 1: Attitudes and Perceptions

Dimensions of Learning

Dimension 1: Attitudes and Perceptions

Dimension 2: Acquire and Integrate Knowledge

Dimensions of Learning

Dimension 1: Attitudes and Perceptions

Dimension 2: Acquire and Integrate Knowledge

Dimension 3: Extend and Refine Knowledge

Dimensions of Learning

Dimension 1: Attitudes and Perceptions

Dimension 2: Acquire and Integrate Knowledge

Dimension 3: Extend and Refine Knowledge

Dimension 4: Use Knowledge Meaningfully

Dimensions of Learning

Dimension 1: Attitudes and Perceptions

Dimension 2: Acquire and Integrate Knowledge

Dimension 3: Extend and Refine Knowledge

Dimension 4: Use Knowledge Meaningfully

Dimension 5: Productive Habits of Mind

Dimensions of Learning

Dimension 4: Use Knowledge Meaningfully

Decision Making

Dimensions of Learning

Dimension 4: Use Knowledge Meaningfully

Decision Making

Problem Solving

Dimensions of Learning

Dimension 4: Use Knowledge Meaningfully

Decision Making

Problem Solving

Invention

Dimensions of Learning

Dimension 4: Use Knowledge Meaningfully

Decision Making

Problem Solving

Invention

Investigation

Dimensions of Learning

Dimension 4: Use Knowledge Meaningfully

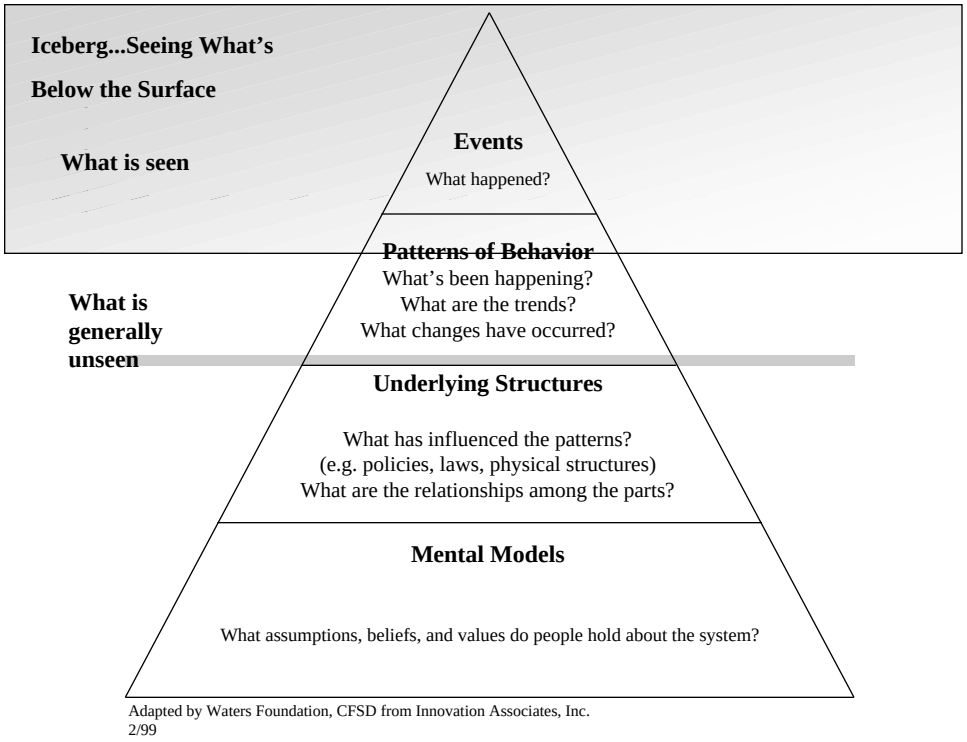
- Decision Making
- Invention
- Experimental Inquiry
- Problem Solving
- Investigation

Dimensions of Learning

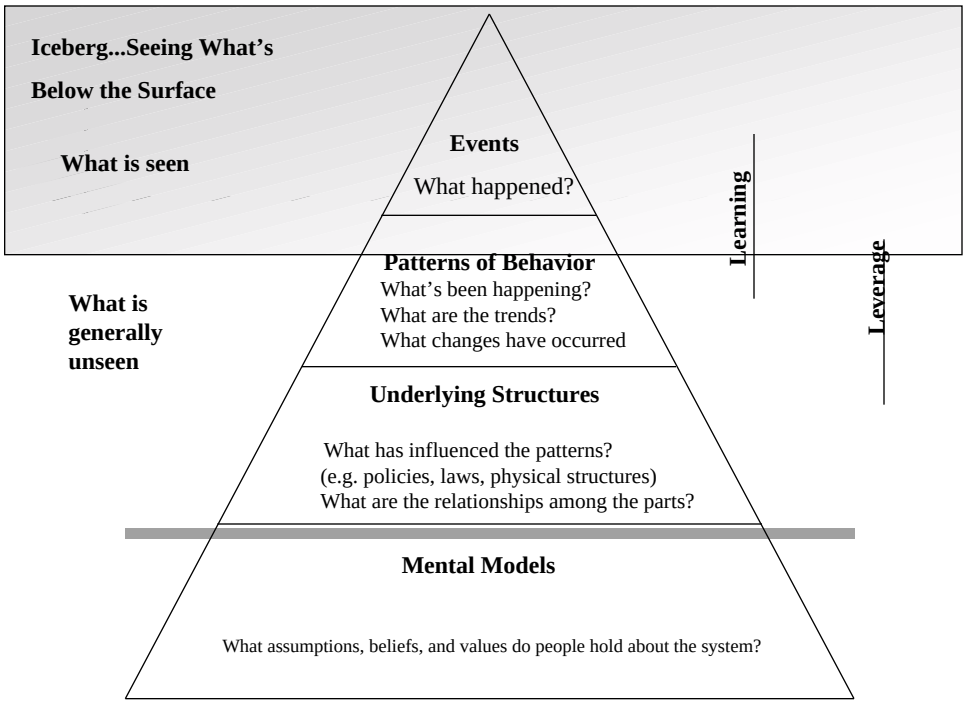
Dimension 4: Use Knowledge Meaningfully

- Decision Making
- Invention
- Experimental Inquiry
- Problem Solving
- Investigation
- Systems Analysis

Systems thinking: Seeing what's below the surface



Adapted by Waters Foundation, CFSD from Innovation Associates, Inc.
2/99



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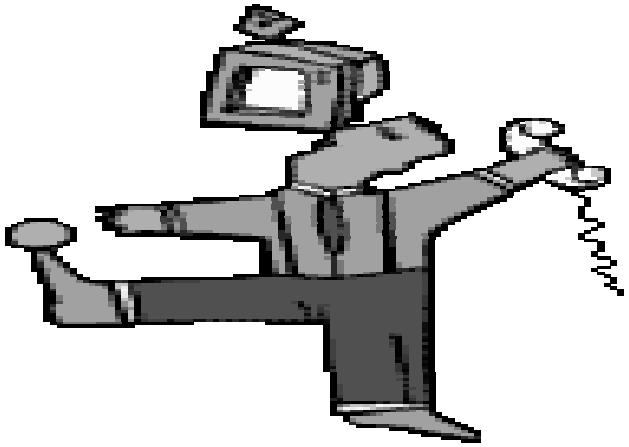
Balancing Tubes Activity



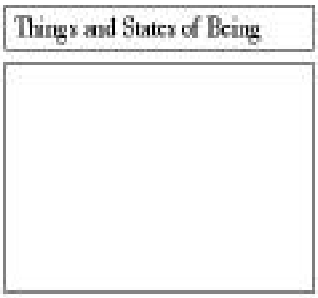
Systems Thinking and Dynamic Modeling Concepts

- Change over time
  - patterns and trends
  - accumulations
- Circular Causality
  - interdependencies
  - reinforcing and balancing relationships
- Leverage
  - structure generates behavior
  - short and long term consequences
  - trade-offs
  - temporal and spatial boundaries

Systems Thinking/Dynamic Modeling Tools & Corresponding Concepts

- Behavior-over-time graph (BOTG)
  - change over time / trends / patterns of behavior
- Causal loop diagram (CLD) (incl. systems archetypes)
  - circular causality / feedback relationships
- Stock/flow diagram (S/F)
  - interdependencies / accumulations
- System dynamics computer model
  - "What if..." / quantitative
- ST/DM games & activities
  - characteristics of complex systems

Accumulations/Stocks



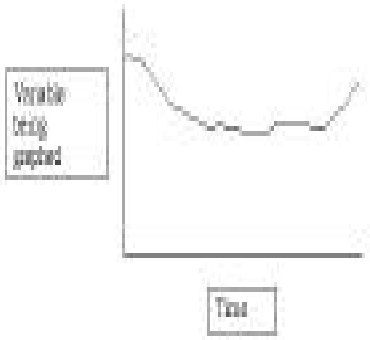
- Nouns, in the STELLA language, are called “stocks.”
- …are represented by rectangles.
- Examples: Water, Population, Cash, Anger, Hunger, Trust, Commitment

Accumulations in the story

•What aspects/variables within the story change?
  •List aspects/variables.

Behavior-Over-Time. . . Graphs

- …show the trend or pattern of change of a variable over time.
- X axis is always time
- Y axis is always the variable being graphed
- …can be drawn on a separate graph form or within stocks.

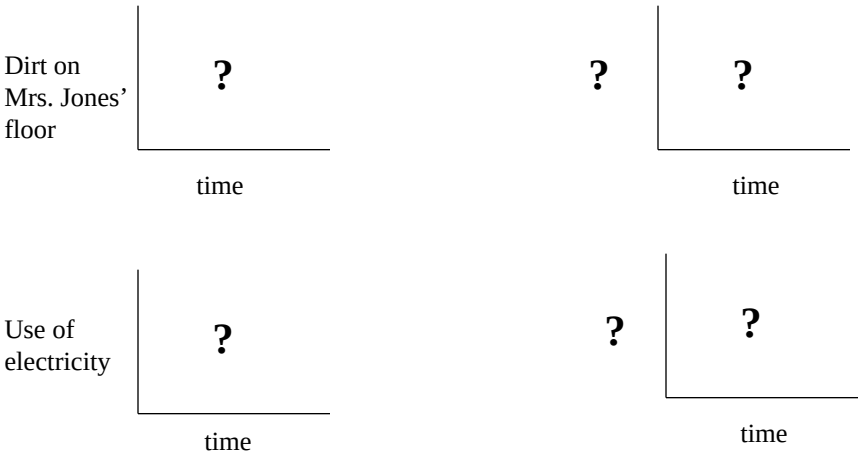


BOTGs from the story

•What aspects/variables within the story change?
  •List aspects/variables.

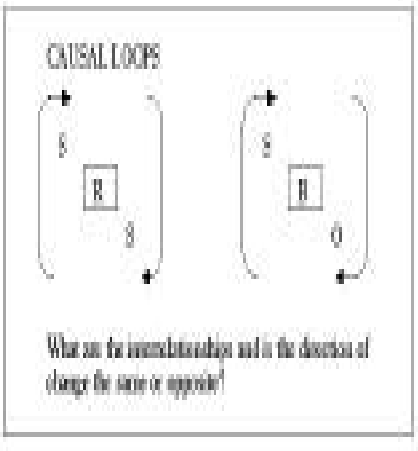
•How does each aspect/variable change?
  •Draw a BOTG of how each aspect changes.

BOTGs from the story

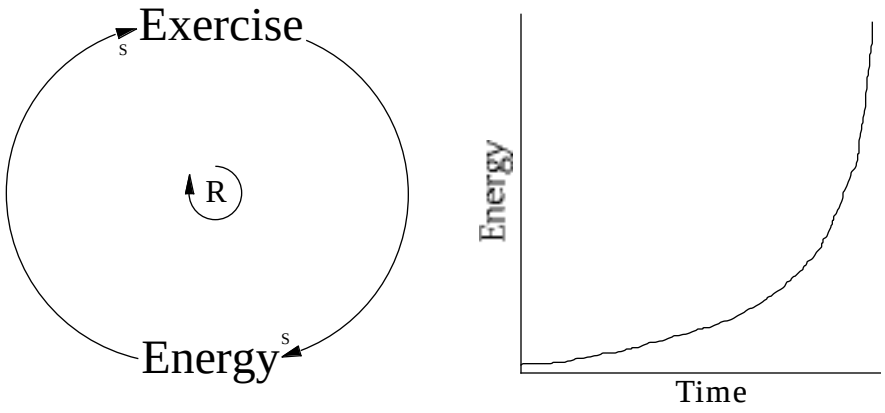


Circular Causality: Causal Loops

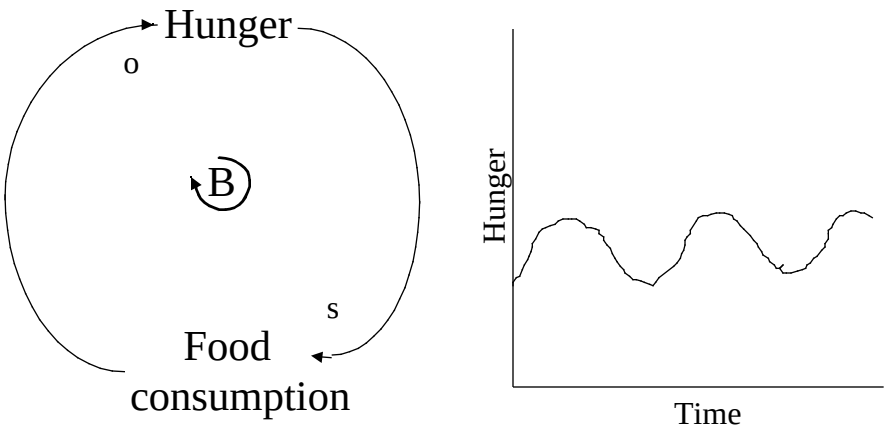
- …show causal relationships and circular feedback within a system.
- A cause becomes an effect, becomes a cause, becomes an effect, and so on.
- Two types: reinforcing and balancing



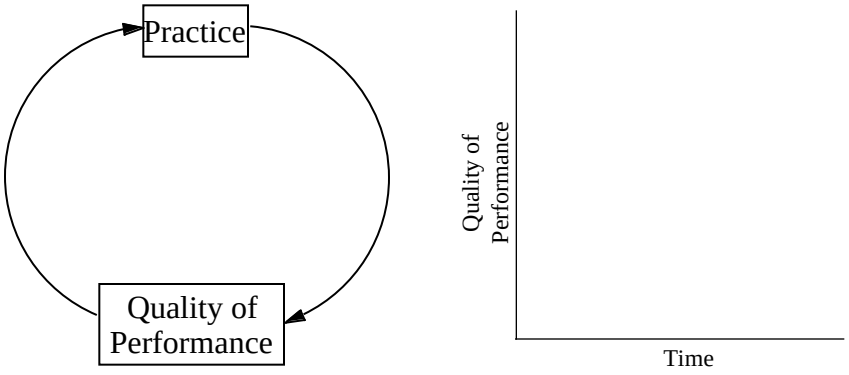
Reinforcing Causal Loop Diagram



Balancing Causal Loop Diagram



Reinforcing or Balancing?



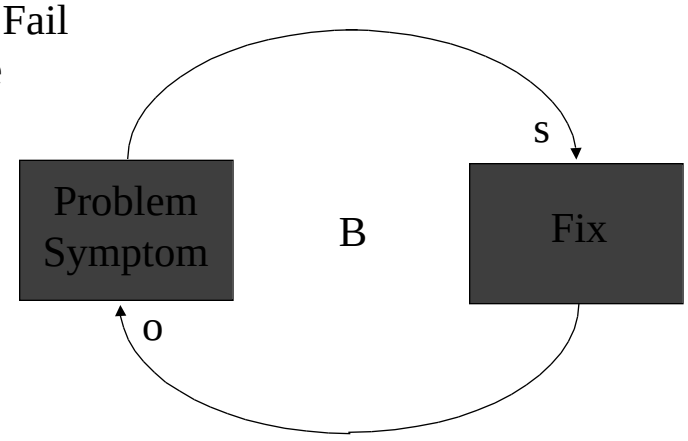
Causal Loop Diagrams from the story

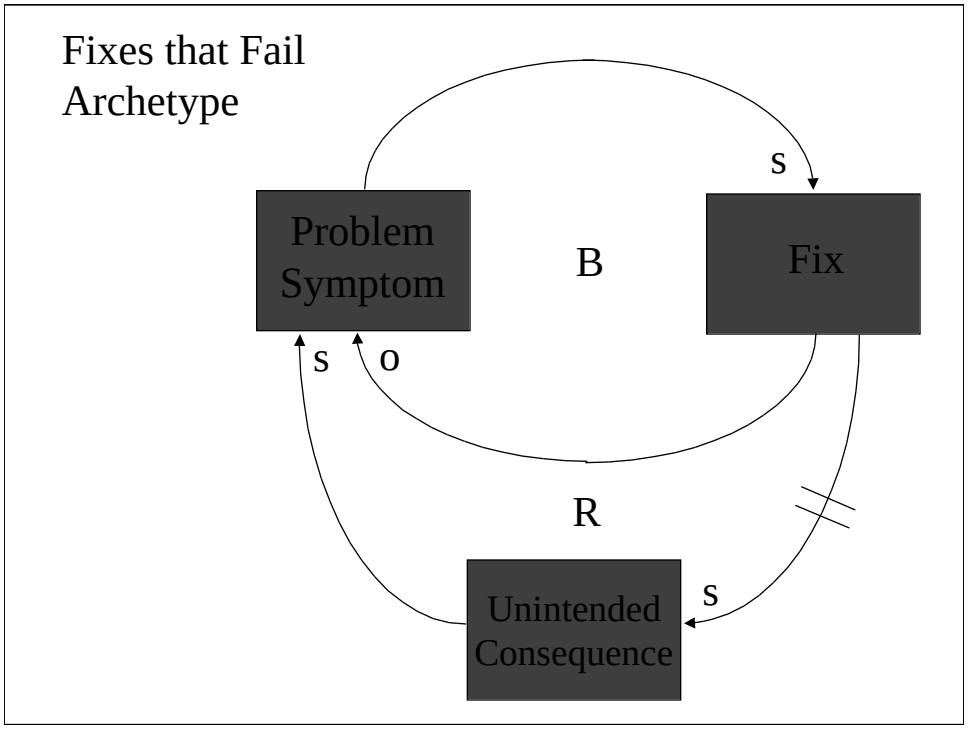
- What aspects/variables within the story change?
  - List aspects/variables.
- How does each aspect/variable change?
  - Draw a BOTG of how each aspect changes.
- How do the identified aspects/variables affect each other?
  - Draw a CLD representing how aspects of the story affect each other. (Refer to the BOTGs/Stocks worksheet.)

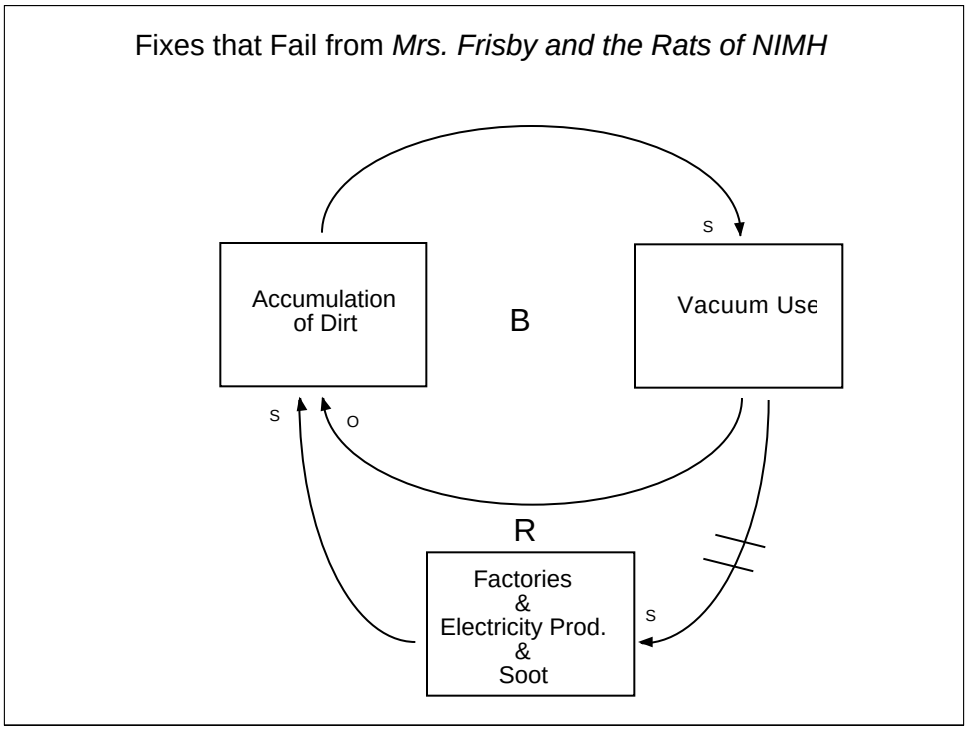
Fixes that Fail Archetype

Problem Symptom

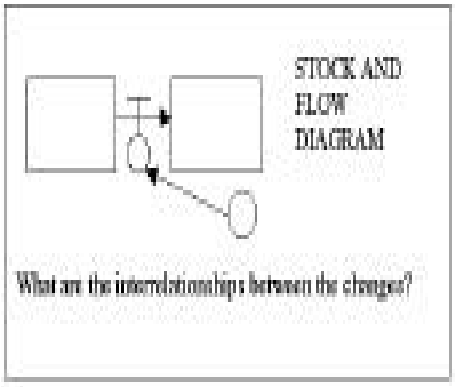
Fixes that Fail Archetype




Fixes that Fail
Archetype
Problem
Symptom
B
Fix
s
s
o
R
Unintended
Consequence
s


Fixes that Fail from *Mrs. Frisby and the Rats of NIMH*
Accumulation
of Dirt
B
Vacuum Use
s
s
o
R
Factories
&
Electricity Prod.
&
Soot
s

Circular Causality: Stock/Flow Diagrams

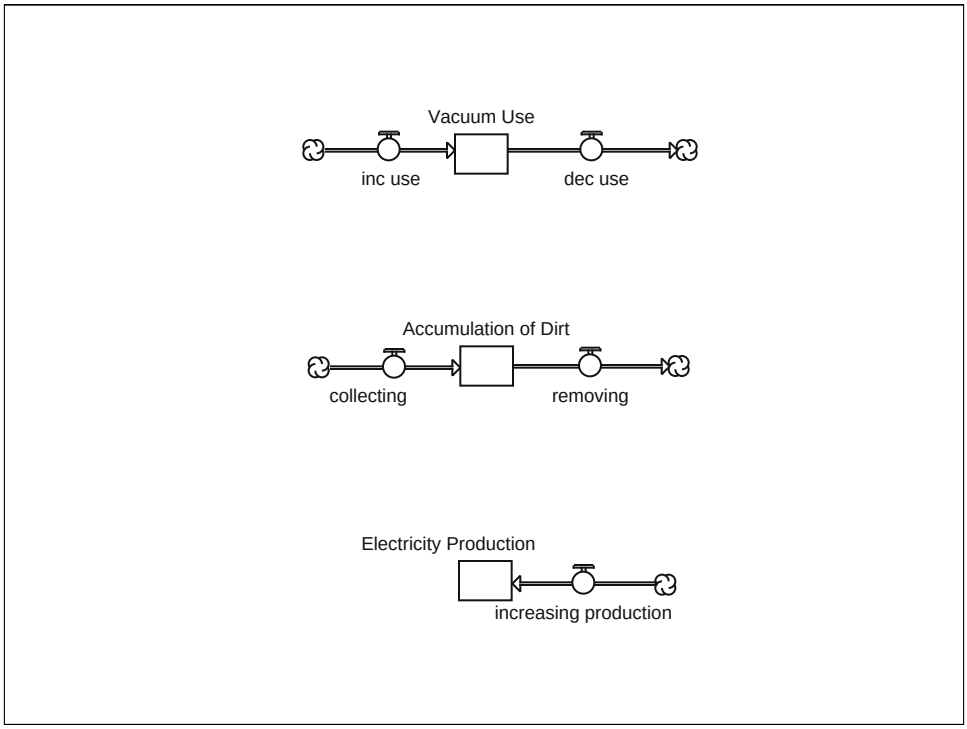


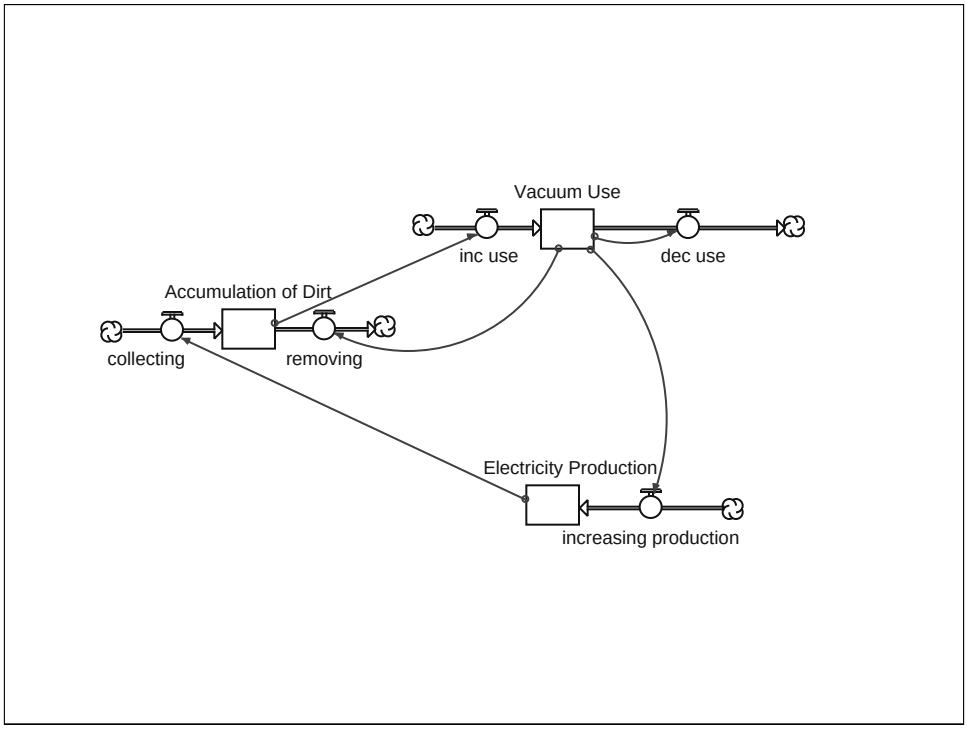
- …show interdependencies and feedback within a system by identifying major accumulations and the factors that increase and decrease over time.
- Icons, which come from dynamic modeling, may also include connectors and converters.

Vacuum Use

Accumulation of Dirt

Electricity Production


Vacuum Use
inc use
dec use
Accumulation of Dirt
collecting
removing
Electricity Production
increasing production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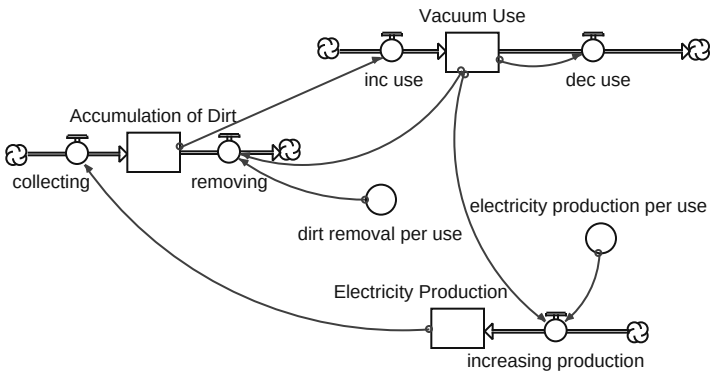

Stock/Flow Diagrams from the story

- What aspects/variables within the story change?
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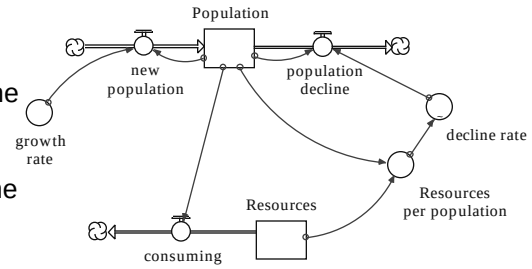
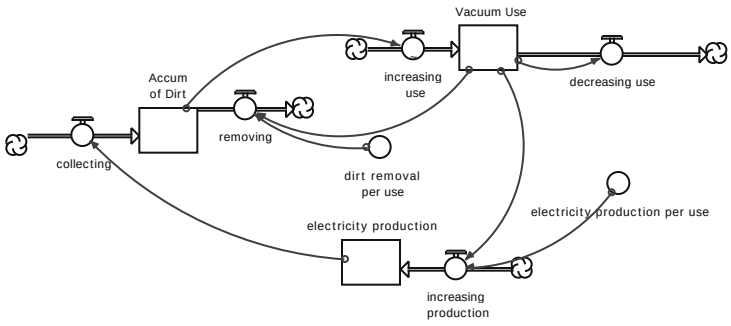
- How does each aspect/variable change?
  - Draw a BOTG of how each aspect changes.
- How do the identified aspects/variables affect each other?
  - Draw a CLD representing how aspects of the story affect each other. (Refer to the BOTGs/Stocks wksht.)
  - Add to the Stock/Flow diagram representing how aspects of the story affect one another.

Dynamic Modeling

- "A computer model of a system is a stock/flow diagram with supporting mathematical equations which link the factors of the system. As changes are made to the factors in the system, the behavior of the system, as indicated by output graphs, changes." (STELLA, HPS-Inc.)

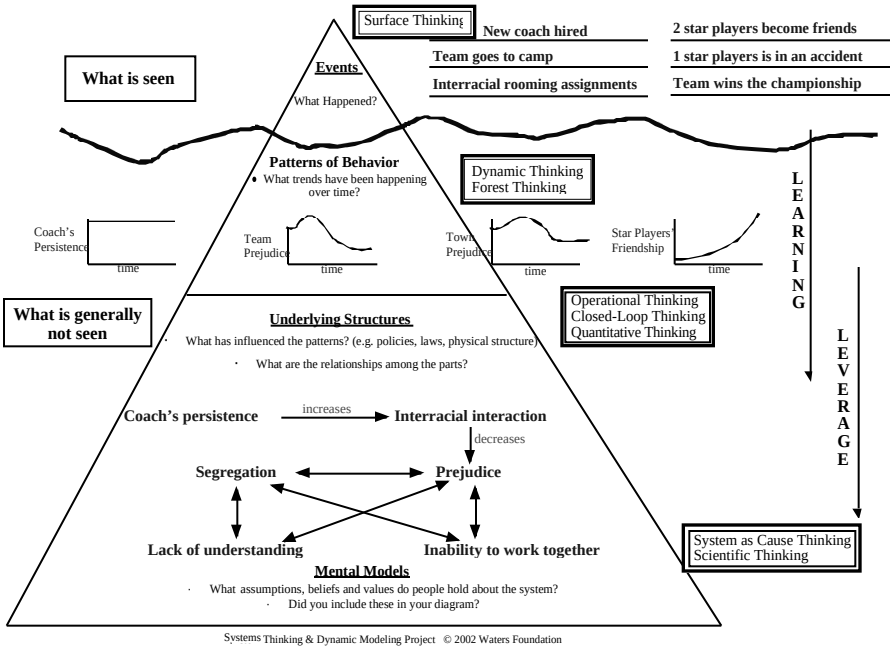


A Simple Dynamic Model from the story



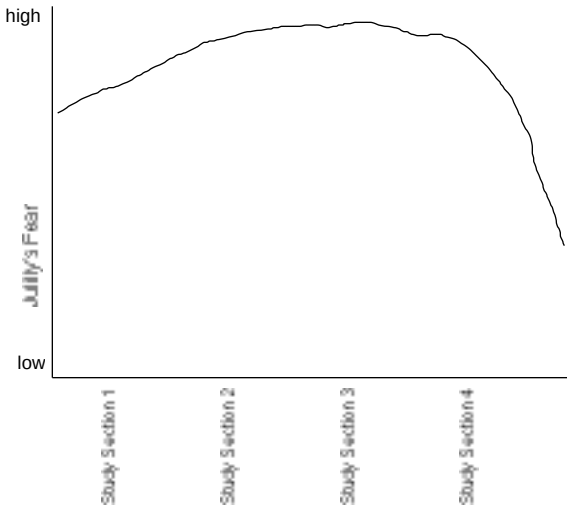
Student Samples

ICEBERG ANALYSIS SAMPLE - *Remember the Titans*



BOTG - Elementary School Literature

BOTG from the book *Run Away to Freedom* (5th grade)



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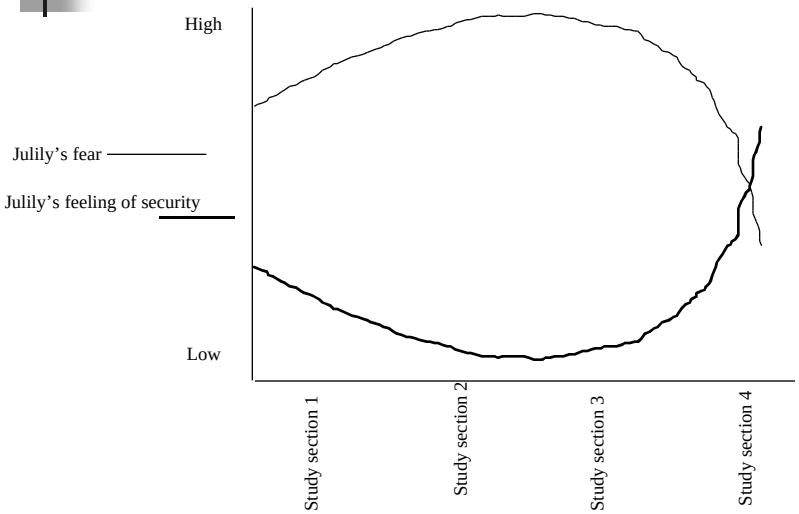
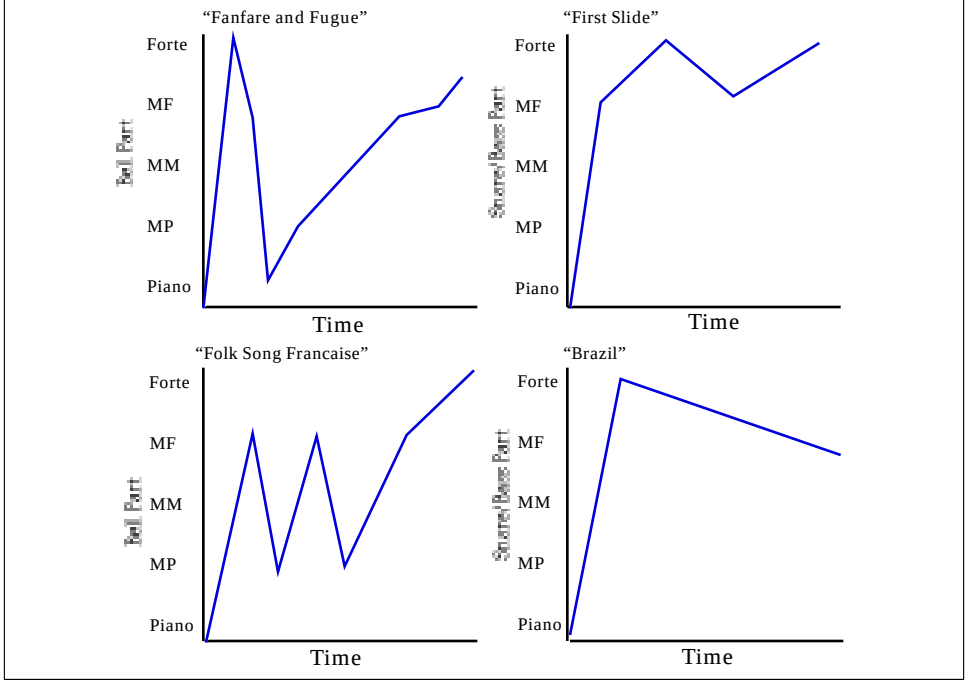
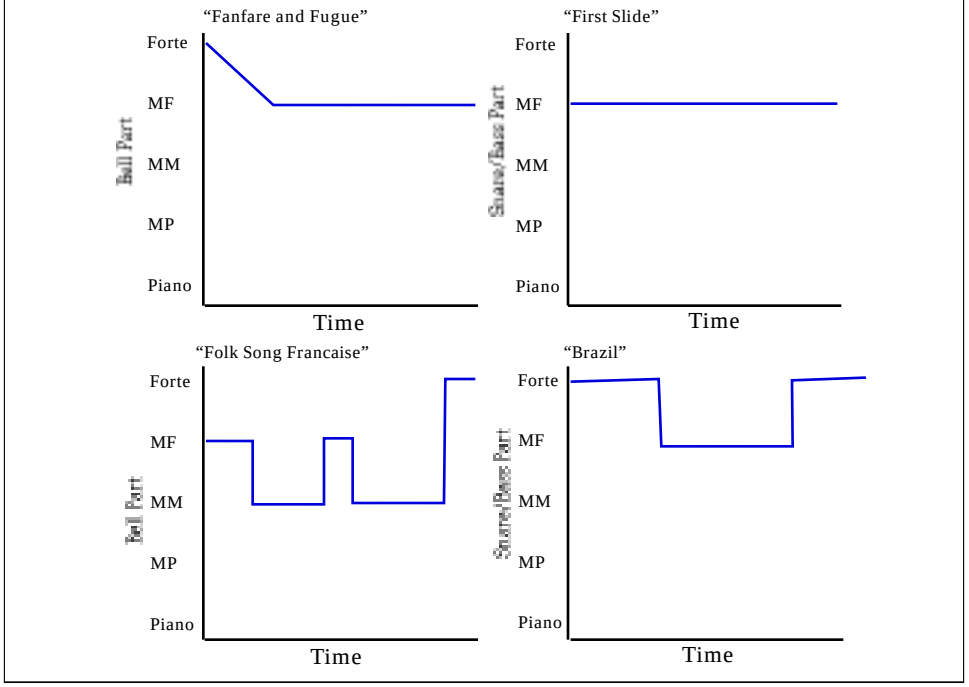


BOTG - Middle School Band

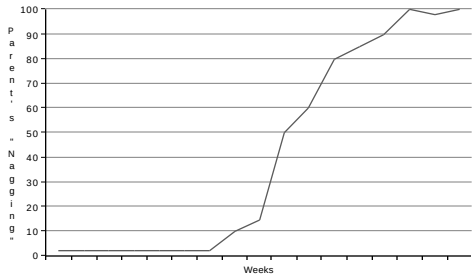


BOTG - Middle School Band - Page 2

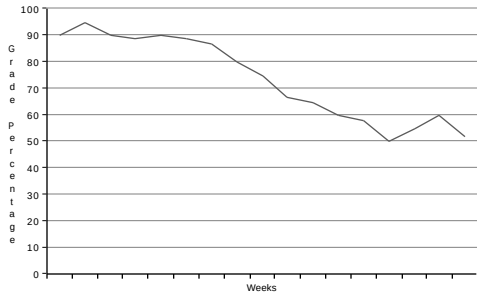


BOTG - Counseling Example

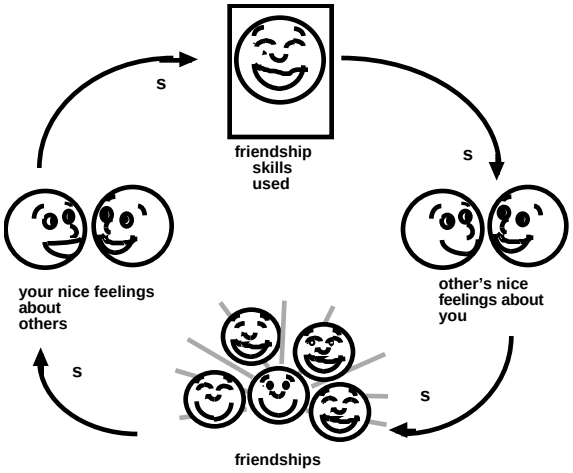
Parents' nagging



Grade percentage

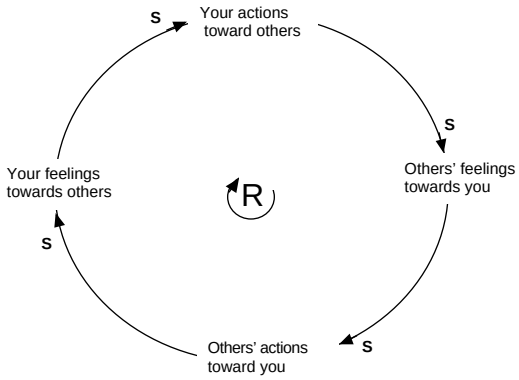


"friendship skills" causal loop diagram



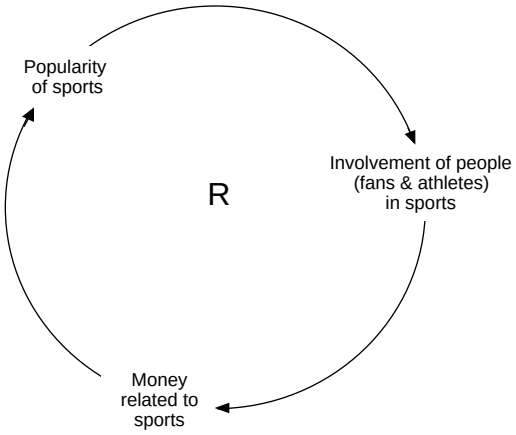
CLD - Elementary School Social Studies

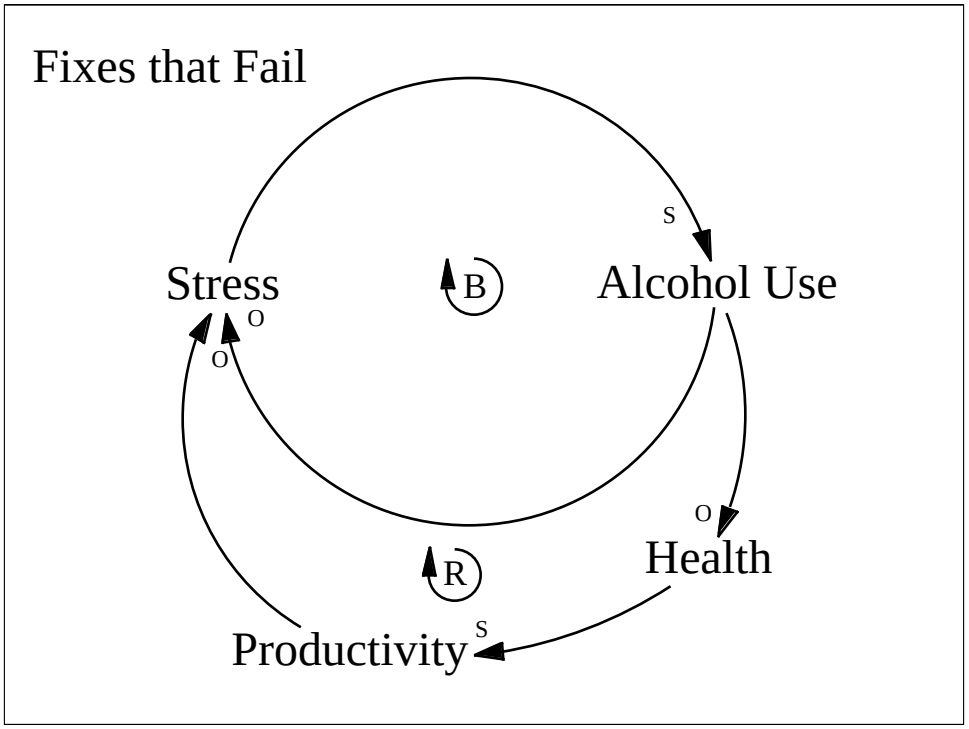
After playing the Friendship Game,first grade students return to their classroom to debrief their experience. This reinforcing causal loop diagram is used with students during this debrief.

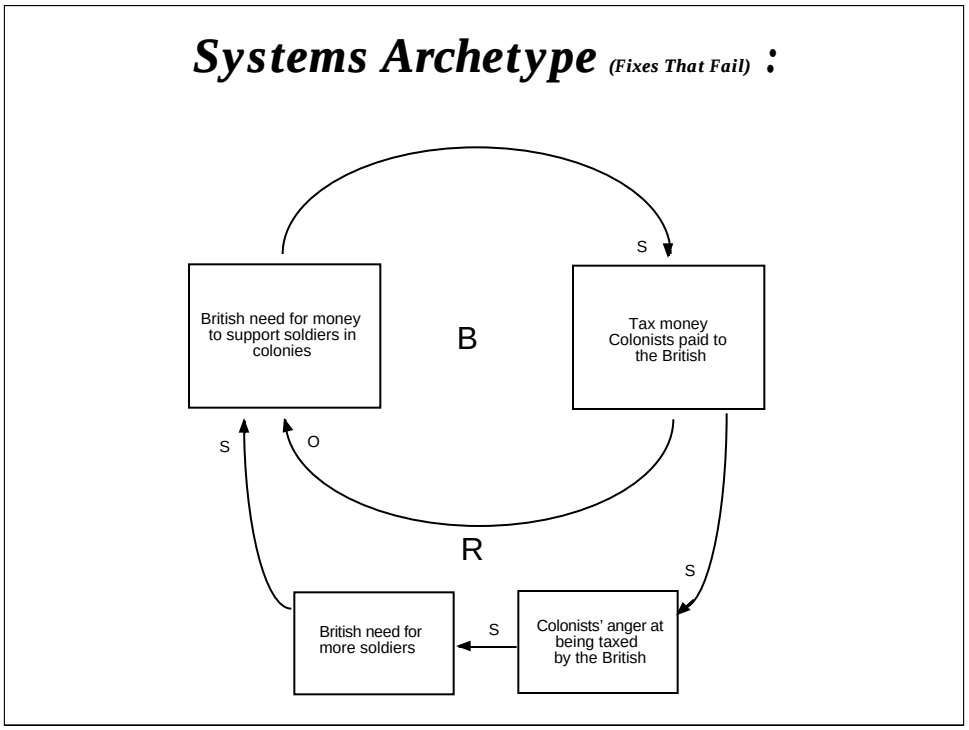


CLD - Elementary School Social Studies

After creating a BOTG which showed the exponential growth of sports in the 1900s, students created a reinforcing causal loop diagram to explain their thinking.

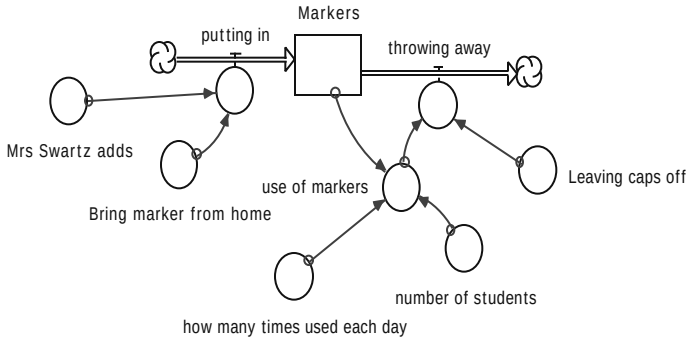



Fixes that Fail
S
Stress
B
Alcohol Use
O
O
O
Health
R
S
Productivity

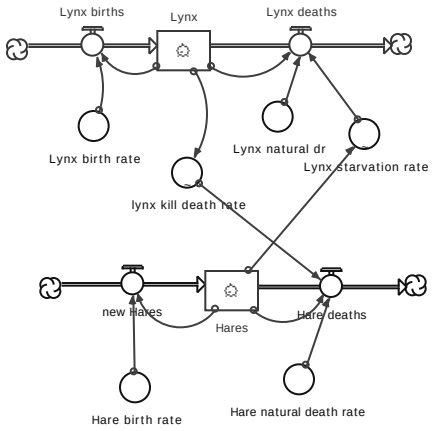

Systems Archetype (Fixes That Fail) :
S
British need for money to support soldiers in colonies
B
Tax money Colonists paid to the British
S
O
R
S
British need for more soldiers
S
Colonists' anger at being taxed by the British

Stock/Flow Map - Elementary School Social Studies -2nd Grade Mini Society Unit

One objective of the Mini Society unit is for students to understand the concept of scarcity. This S/F map was used to examine the accumulation and drain of markers in the 2nd grade classroom.



Lynx and Hares Simulation- Middle/High School



Action Research

- "The students demonstrated their understanding of the concept of archetypes and were able to identify examples and analyze connections between the past and the present. The results indicate that the use of systems tools is very beneficial to students' ability to identify and make connections between the past and the present and thus 'learn' from history." (7th grade social studies)
- "…overall, parents seemed to have a sense of what their children are capable of in terms of higher level thinking and presenting to an audience." (7th grade literature)
- "It is clear, however, that STELLA enhanced my pre-calculus students' understanding of the fundamental natures of each of the types of functions." (High school pre-calculus)

Action Research (cont.)

- "Over 90% of my students indicated that using SD modeling helped them or greatly helped them understand linear concepts." (6th grade math)
- " …70% of the students met the criteria of performing at a 4 or better on the assessment rubric, the noted increase from 30% demonstrates significant growth proving this is without a doubt a powerful way to assist students in integrating inferences, interpretations, and conclusions into their writing." (6th, 7th, 8th grade math)
- "Feedback in water systems is a highly abstract concept, and while many students struggled to understand the multiplicity of feedback loops here, they were able to grasp the idea of at least 2 successive effects from one initial water chemistry imbalance within their case study." (High school chemistry)
- Using STELLA modeling to assess environmental impact, 100 % rated at meets or exceeds standard - change from over 50 % not meeting during pre-assessment. (High school field study)

Student Quotations

- "Can we use BOTGs for our next writing assignment? It makes writing so easy."
- "It helps doing the simulation because I understand the book better."
- "…that math is a very important part of graphs and the simulations. It is like a language in a way. Math isn't just numbers. It is actually saying something."
- "Patterns are recognizable everywhere and it's easy to notice them. We can relate our lives to these patterns to help ourselves."

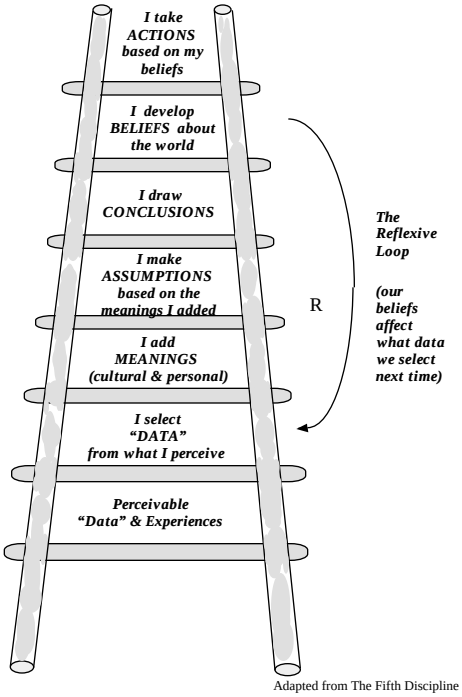
STUDENT QUOTATIONS (cont.)

- "You can do anything if you set your mind to it, no matter how young you are or how many problems you run into."
- "It improves the life skills of basic problem solving and interacting with co-workers and family because you are better at perceiving behaviors."
- In the past three years, an average of 74% of the seniors (in CFSD) surveyed in the spring answered yes to this question: Was using SD concepts/tools/simulations an effective means for you to learn class material?

WAYS TO LEARN MORE

- Web Sites
- Resource Materials
- Training and Workshops
- Site Visits
- Conferences

Ladder of Inference

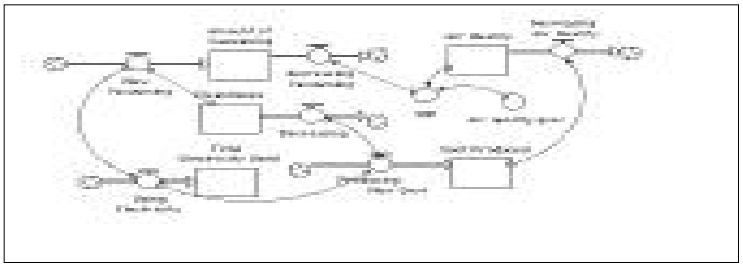


Adapted from The Fifth Discipline Fieldbook Last modified - 1/1999

THE STORY OF MRS. JONES AND HER VACUUM CLEANER
Examples of causal loops and stock and flow diagrams

Causal Loop Diagrams

R = reinforcing feedback
B = balancing feedback



Stock and Flow Diagram
Uses icons of dynamic modeling but can be drawn on paper.
Reinforcing and balancing interrelationships are represented in a more explicit manner.